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Gas Panel

Solid Particle Material Handling & System Integration

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In this ground-breaking paper, Worley and Princeton University’s Andlinger Center for Energy and the Environment explore the practical shifts required to develop and deliver the energy infrastructure needed to achieve our net-zero ambitions.

The focus of this paper is on supply-side energy infrastructure, outlining the five key shifts in thinking needed to deliver a net-zero transition. It will help you understand the scale of the task. And demonstrate how a combination of all five shifts is how we make net zero a reality.

We are a global leader in energy transition solutions
Particle Handling Design Criteria & Considerations

1) Sand is abrasive – wear must be mitigated
2) Sand is potentially friable – gentle conveying is required
3) Sand produces silica dust (inc. respirable): minimize dust emissions + technology to handle dusty environment
4) Sand is totally dry and free flowing
5) Heat loss to be minimized throughout
6) Parasitic load to be minimized (high lift efficiency)
7) Minimum practical mechanical components exposed to sand/temperature
8) CAPEX to be minimized
9) High reliability/availability
10) Simple maintenance where practical
11) Design must allow for thermal expansion (~1% for SS)
12) Multiple streams for commercial application can give redundant capacity, too many becomes O&M problem: ideally handle lift in one stage

Ideal technology is already commercially proven for capacity, lift height, and temperature (or can be easily modified to meet the criteria)

Phase 3 Demonstration (1 MWt) Project Sizing Info
• 64 mt/h (43 m³/h)
• 44 m lift
• 7.7 kW theoretical lift power
• 570°C

Commercial Scale (33-100 MW) Indicative Sizing Info
• 4,500 – 13,000 mt/h (3,000 – 8,700 m³/h)
• 155 – 250 m lift
• 1.9 – 8.8 MW theoretical lift power
• 570°C
Particle Handling Technology Screening Investigation

**Pneumatic (pressure)**  
[Ph3: Yes, Commercial: No]

**Pros:**
- Contained system
- Versatile arrangement
- Dense phase can limit wear
- High temp experience
- Simple pipe insulation concept

**Cons:**
- Need to heat feed air (recuperator w/ return air)
- Poor lift efficiency
- Capacity & lift limitations
- Need separators (cyclone)

**“Small Skip” / Case Conveyor & Vertical Spiral Conveyor**  
[Ph3: Yes, Commercial: No]

**Pros:**
- Mech parts external to sand
- Sealed & insulated skips (low Qloss)
- No thermal expansion issues
- High lift efficiency

**Cons:**
- Skips/cases need multiple handling & batch feed
- Complex loading & unloading
- Capacity & lift limitations
- High power fluctuations

**Olds Elevator™ (fixed screw, rotating tube)**  
[Ph3: Possible, Commercial: No]

**Pros:**
- Good dust containment
- High temp experience (Sandia)
- Drive components external to sand
- Low wear

**Cons:**
- Capacity & lift limitations
- Poor lift efficiency
- Particle attrition
- One supplier

**Bucket Chain Elevator**  
[Ph3: Yes, Commercial: Possible]

**Pros:**
- Mature technology, versatile
- Temp contained in box casing
- Low speed can limit wear, attrition, dust
- Good lift efficiency

**Cons:**
- Mech parts in sand/temp contact
- Bulky (SS+ materials req’d)
- Chain replacement= high O&M $
- Capacity & lift limitations
- Need to remove dust from casing

**“Big Skip” Mine Hoist**  
[Ph3: Yes, Commercial: Yes]

**Pros:**
- Mech parts external to sand
- Sealed & insulated skips (low Qloss)
- No thermal expansion issues
- High lift efficiency
- Best-in-class for commercial mt/h + lift

**Cons:**
- Batch feed
- Complex loading
- High power fluctuations
- Raises tower height

**Redler / En-Masse / Chain Conveyor**  
[Ph3: Possible, Commercial: No]

**Pros:**
- Mature technology, versatile
- Dust/temp contained in box casing
- Low speed can limit wear, attrition, dust
- Good lift efficiency

**Cons:**
- Mech parts in sand/temp contact
- Bulky, costly (SS+ materials req’d)
- Chain replacement= high O&M $
- Capacity & lift limitations
- Need to remove dust from casing

Pneumatic-vacuum, screw conveyors, capsule pipeline, tube conveyor (chain), vibrating screw, Magaldi EcoBelt, Rail-Veyor, Light Rail, RopeCon, troughing belt, apron feeder, chain grate conveyors, spiral tube, Flexicon helical conveyor discounted
Technology Selection for Phase 3 & Commercial

### Phase 3 Demonstration

- Desire to use same technology in Phase 3 as commercial for de-risking purposes
- Single drum hoist, ground mounted, w/ 1 overturning (Kimberly) insulated skip
- ~50% lifting efficiency
- Add’l cost and complexity of balanced double drum hoist w/ 2 skips not justify increased lift efficiency for demonstration project

### Commercial System

- Mine skip hoist needs fewer lifts vs bucket elevator (B/E). B/E needs multiple lifts in series & parallel, resulting in reliability/availability/O&M risks:
  - Multiple (parallel) double drum hoist, ground mounted, w/ 2 overturning (Kimberly) insulated skips.
  - ~80%+ lifting efficiency

SIEM AG TECBERG & ABB engaged to provide input on preliminary design and cost estimates for Phase 3 and Commercial
Phase 3 Demonstration Project 10 MW\textsubscript{t}-h TES Design

- 212 MT net storage, ea.
- Hot & cold silo substantially similar
- Funnel flow
- Square steel silo, pyramidal hopper w/ stiffener rings
- Thermo-mechanical FEA using Advisian’s proprietary FLEXAS\textsuperscript{®} accelerated solver
- Internal insulation
- Internal SS wear liner w/novel design to accommodate thermal expansion
- Maximize shop fabrication
3 receivers (N, SW, SE)
- skip hoist on South
- skip unloading penthouse=grey
- hot & cold TES silos=orange
- hoist house= white steel box @ grade
- sCO₂ piping=yellow
- BOP=light blue (e.g. air comp + receiver, baghouse for silica dust removal)

Phase 3 Demonstration System Integration - 3D Model

Looking NW

Looking ~East

Looking North
Phase 3 Demonstration System Integration - 3D Model

Receiver Deck @ 33m (108’)

unloading hopper

skip (dump position)

day bin
Commercial System Input

Majority of Advisian scope based on Phase 3 Demonstration project design and cost estimate

LCOE Optimization Support:

- Developed cost functions for mine skip hoist and bucket elevator for 10MW - 100MW towers
- Performed conceptual design and associated cost estimates for 10MW - 100MW towers, foundations, and integral TES silos

100MWe Receiver Modular Consulting:

- Receiver assembly layout for modularization
- Module fabrication estimate (overseas) with input from Worley fab shops
- Module shipping and site installation estimate
THANK YOU

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